

Assessing Security as a System Property via Simulation and Measurement

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Talk Outline

- **Introduction**
- **Theoretical Models**
- **Experimental Evaluation**
- **Computational Models**
- **Conclusion**

What is Security as a System Property?

**Security is concerned when an
Environment negatively affects the
technical or social system**

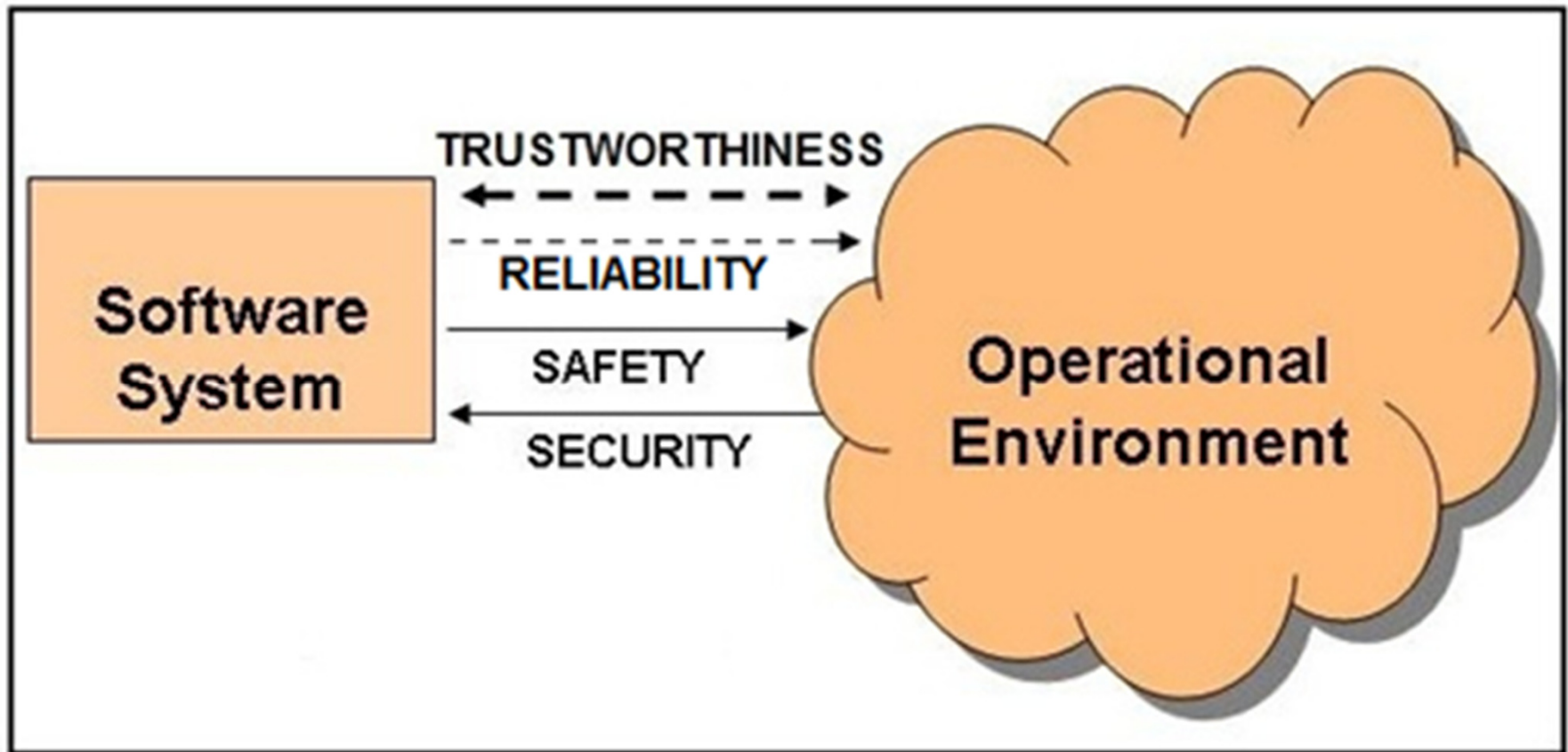
Social system example:

Wikileaks release of classified information

Technical system example: STUXNET

One practical definition (there are many, similar, others) ;

security. In computing, the degree to which information is protected from unauthorized access, given that authorized access is not denied.



Relationship between the computer/software system and its operational environment

In terms of computer/software failures & risks:

- **Security** is concerned when a failure leads to severe consequences (high risk) to the computer system itself.
- **Safety** is concerned when a failure leads to severe consequences (high risk) to the environment.
- **Reliability** is concerned when failure does not lead to severe consequences (high risk) to the environment or a computer system, nevertheless the failure rate is of principal concern.

Problem

We are missing good (any) measures to characterize non-functional software properties related to trustworthiness (safety, security, dependability, etc.), as opposed to timing properties, for example: responsiveness, timeliness, schedulability, predictability.

A suggestion: Apply Science.

**“It is an old saw that science has three pillars: theory, experiment, and simulation.”
Glimm and Sharp, Complex Fluid Mixing
Flows: Simulation vs. Theory vs.
Experiment. SIAM News. 39, 5 (June 2006)**

**This principle is broadly applied in physics,
the mother of modern sciences, but it has
been also adopted in computing.**

How to assess security (safety or other trustworthiness properties) before or during the system's operation (to make predictions)?

- **Theoretical Assessment (analytical model).**
- **Actual Experiments (measurements).**
- **Simulation (numerical calculations).**

Analogy (if one wants to understand the concept better):

How to assess network's properties before it is put into operation?

- **Theoretical Assessment (queuing model)**
- **Actual Experiments (measure throughput, latency, etc.)**
- **Simulation (numerically calculate).**

**Theoretical models of security do exist,
but they are difficult to develop & verify.**

**We're a long way from establishing a
science of security comparable to the
traditional physical sciences, and even
from knowing whether such a goal is
even achievable.**

**Evans & Stolfo, IEEE Security & Privacy,
May/June 2010)**

**[http://www.cs.virginia.edu/~evans/
pubs/sos2011/introduction.pdf](http://www.cs.virginia.edu/~evans/pubs/sos2011/introduction.pdf)**

- **A measure of a system property is a computable function from the set of features into a set of real numbers.**
- **Security threats are never completely defined, thus, respective system property to prevent security breaches is non-measurable.**

**Mark D. Torgersen, “Security Metrics for Communication Systems,”
12th ICCRTS Int’l Command and Control Research and Technology
Symposium, Newport, RI, June 19-21, 2007**

http://www.dodccrp.org/events/12th_ICCRTS/CD/html/papers/108.pdf

Our Approach to Theory

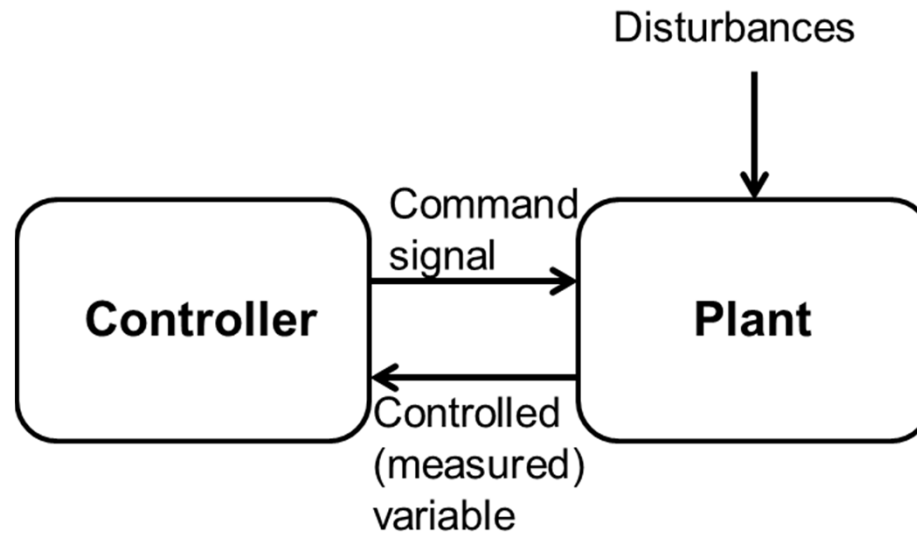
- **Uncertainty is built into models, even if data items are missing**
- **Rough Sets theory deals with such issues**
 - **Not a subject of this presentation**

Measurement and Simulation

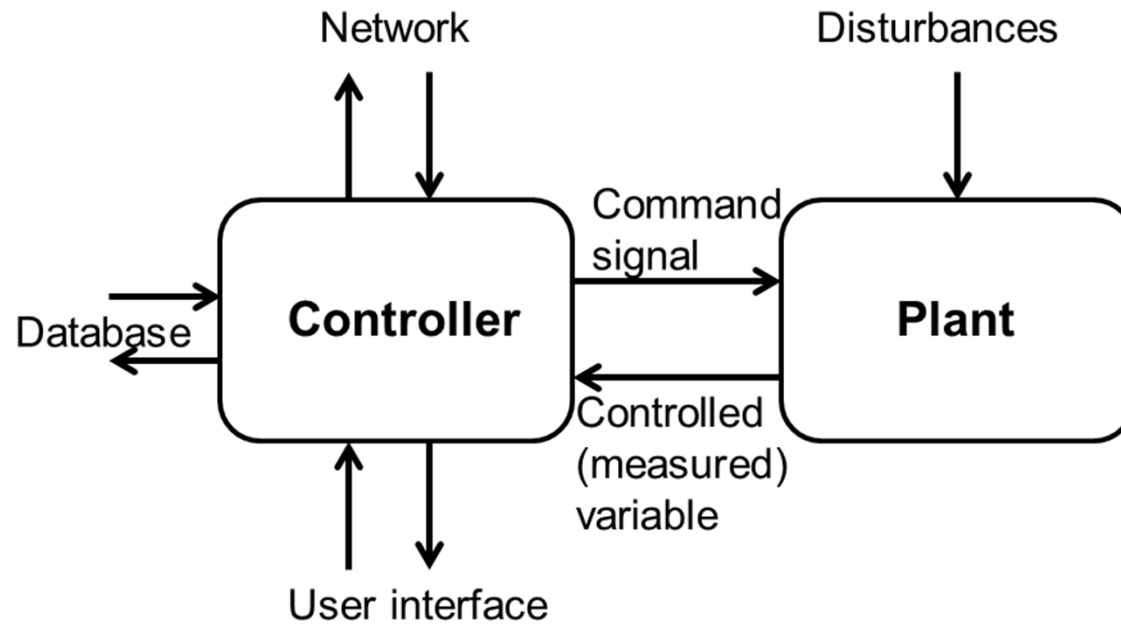
Particular classes of systems considered (relevant to military applications):

- **Embedded Systems**
- **Industrial Control Systems**

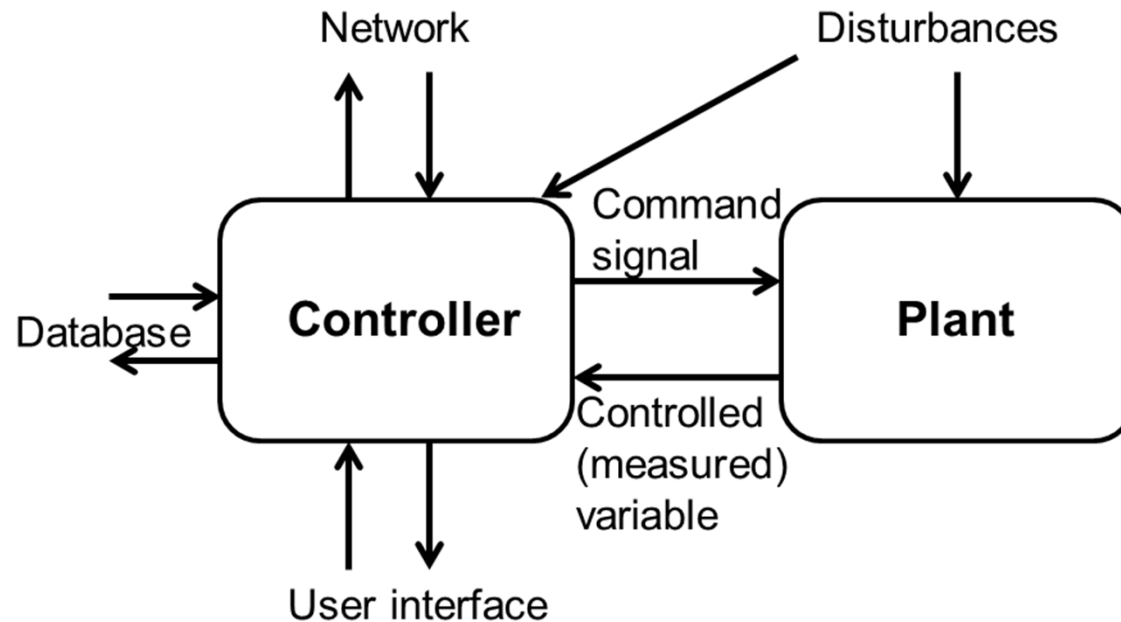
Generic Model of a Control System



Generic Model of a Control System (with all applicable interfaces)

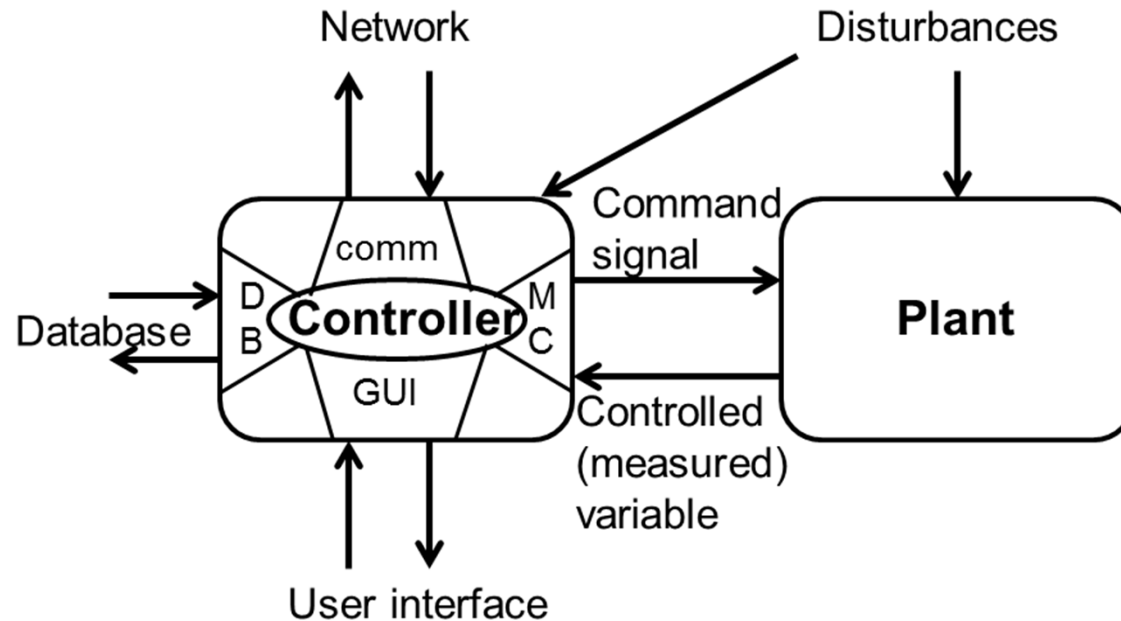


Generic Model of a Control System (with all applicable interfaces and disturbances related to Threats)



Generic Model of a Control System

(with all applicable interfaces and disturbances related to Threats and relevant guards to protect the system)

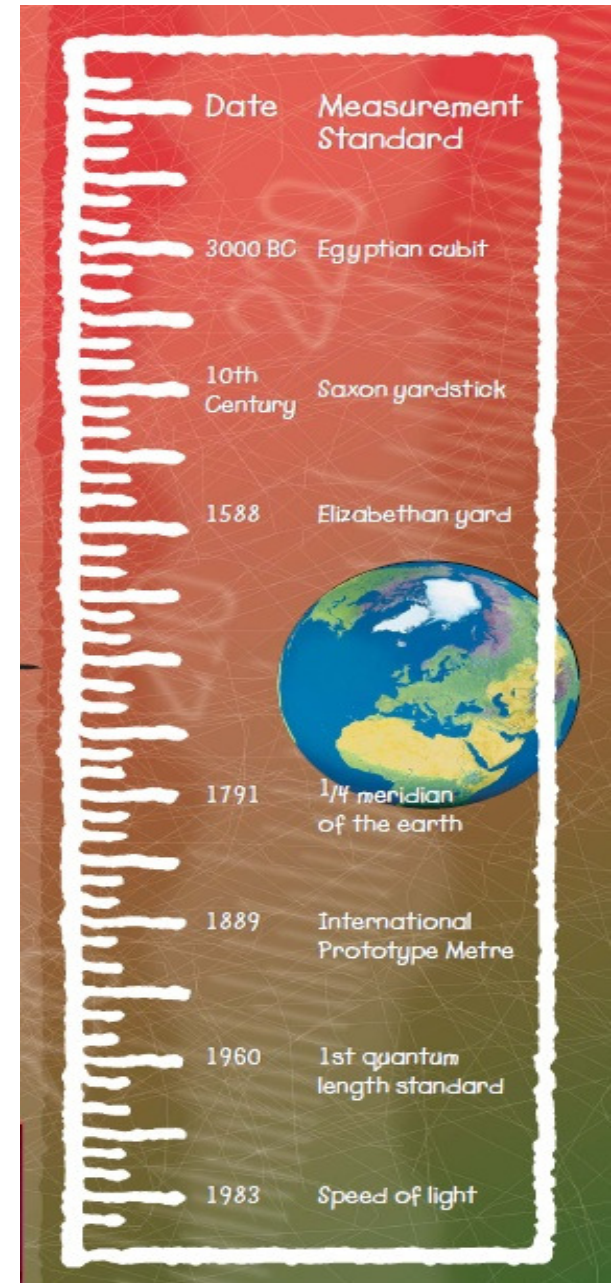


Our Approach to Measurements

- **Take a closer look at the analogy with physical measurements**
- **Length/distance, Time, etc.**
- **Apply software tools**
- **Adopt results from safety assessment**

How to Measure Length?

Henry I is believed to decree that a yard should be “the distance from the King’s nose to the end of his outstretched thumb.” (source: NPL)



What Do We Need to Measure?

Property - length

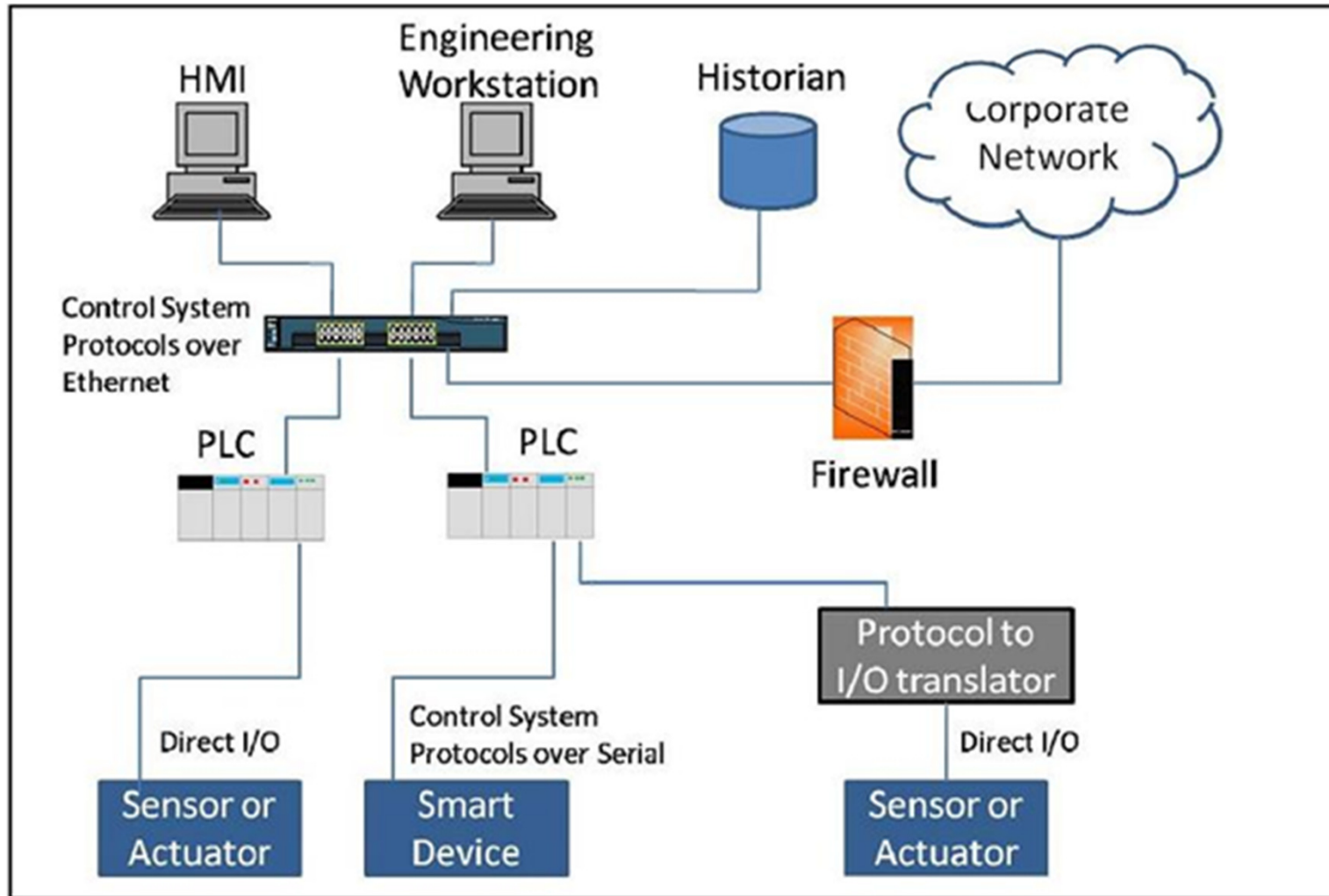
Metric - meter

Measure - device

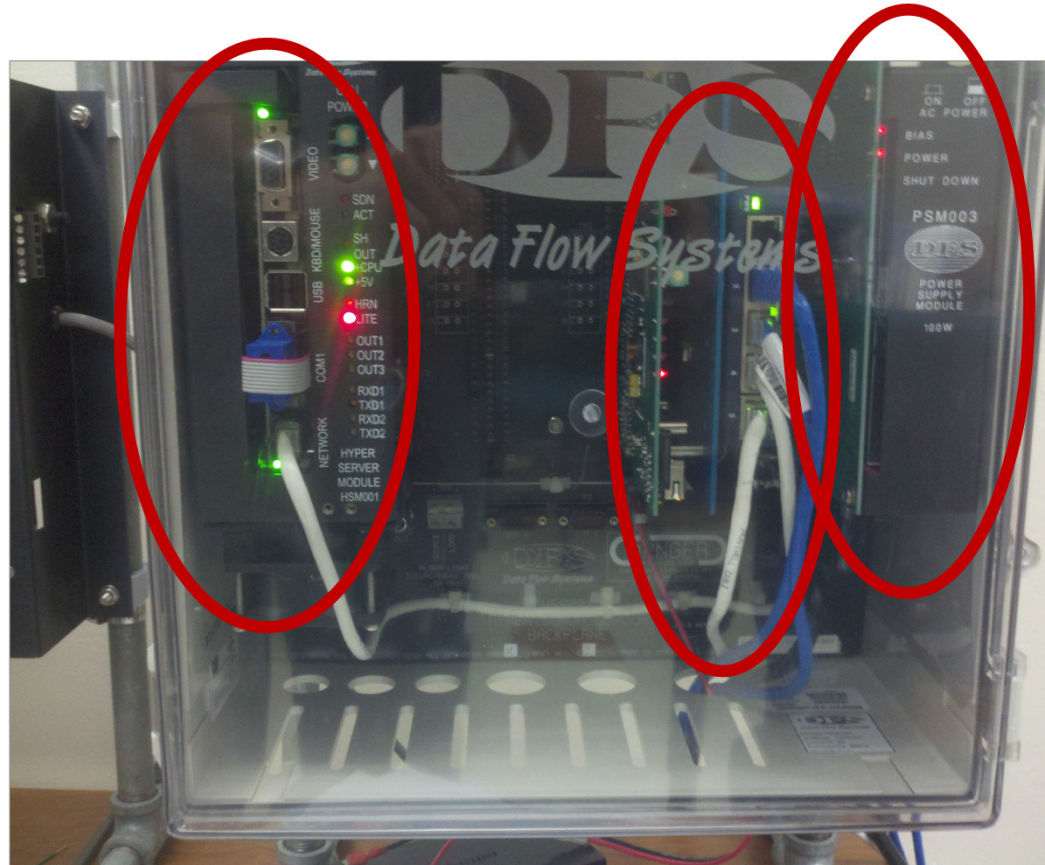
Definition of a metric (meter).

The *meter* is the length of the path traveled by light in vacuum during a time interval of $1/299\,792\,458$ of a second.

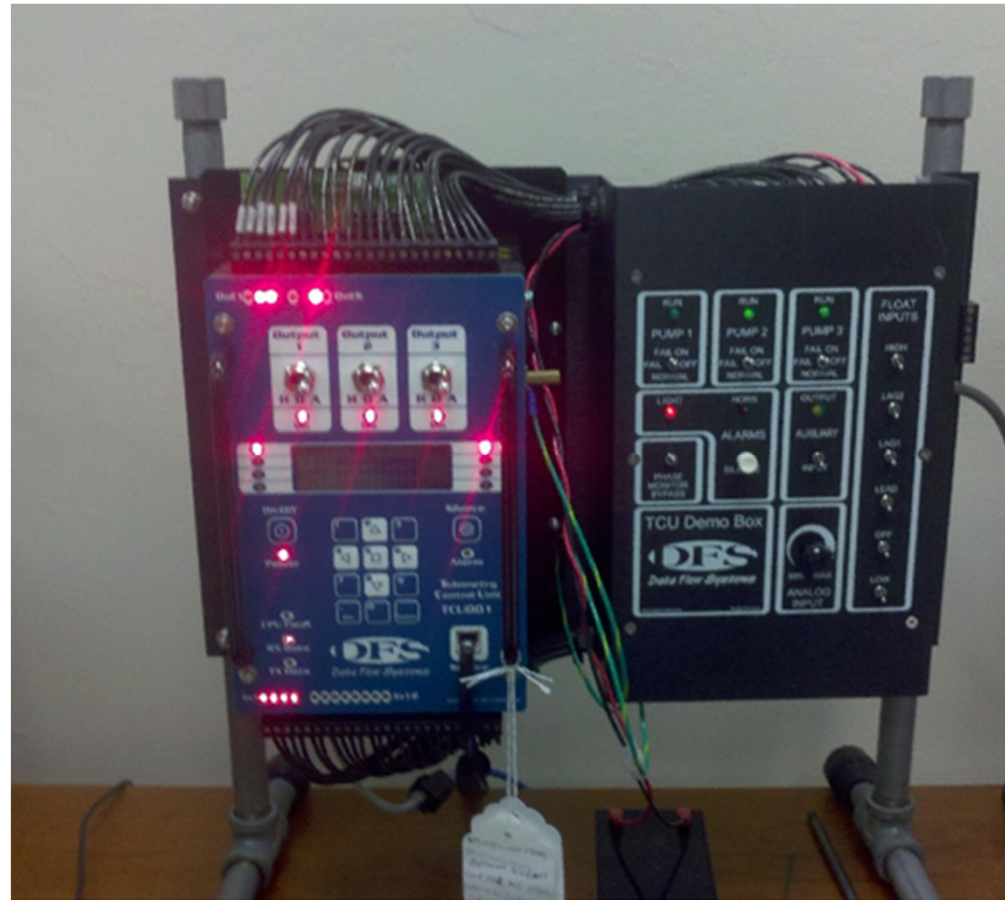
Model of an Industrial Control System for Experiments



SCADA System Controller at Florida Gulf Coast University



Remote Unit of the SCADA Control System at FGCU



Investigation of potential threats with netstat (TCP)

```
[mgr@HyperTACII mgr]$ netstat -at
Active Internet connections (servers and established)
Proto Recv-Q Send-Q Local Address           Foreign Address         State
tcp      0    268 HYPERTACII:ssh         69.88.163.28:4032      ESTABLISHED
tcp    8217      0 HYPERTACII:ssh         69.88.163.28:3818      CLOSE_WAIT
tcp      0      0 HYPERTACII:dfsinfo     69.88.163.28:1086      ESTABLISHED
tcp      0      0 HYPERTACII:dfsinfo     69.88.163.28:1906      ESTABLISHED
tcp      0      0 HYPERTACII:dfsinfo     69.88.163.28:1143      ESTABLISHED
tcp      0      0 HYPERTACII:dfsinfo     69.88.163.28:1139      ESTABLISHED
tcp      0      0 *:dfsinfo              *:.*                    LISTEN
tcp      0      0 *:mysql                 *:.*                    LISTEN
tcp      0      0 *:www                   *:.*                    LISTEN
tcp      0      0 *:https                 *:.*                    LISTEN
tcp      0      0 *:printer               *:.*                    LISTEN
tcp      0      0 *:ssh                   *:.*                    LISTEN
tcp      0      0 *:ftp                   *:.*                    LISTEN
tcp      0      0 *:time                  *:.*                    LISTEN
tcp      0      0 *:telnet                *:.*                    LISTEN
tcp      0      0 *:shell                 *:.*                    LISTEN
tcp      0      0 *:login                 *:.*                    LISTEN
tcp      0      0 *:finger                *:.*                    LISTEN
tcp      0      0 *:auth                  *:.*                    LISTEN
tcp      0      0 *:1024                  *:.*                    LISTEN
tcp      0      0 *:sunrpc                 *:.*                    LISTEN
```

Investigation of potential threats with netstat (UDP)

```
Udp      0      0 *:dfsvoice      *.*
udp      0      0 *:1044          *.*
udp      0      0 *:1043          *.*
udp      0      0 *:1042          *.*
udp      0      0 *:1041          *.*
udp      0      0 *:1040          *.*
udp      0      0 *:1039          *.*
udp      0      0 *:1038          *.*
udp      0      0 *:1037          *.*
udp      0      0 *:dfshsupport   *.*
udp      0      0 *:driver6       *.*
udp      0      0 *:driver5       *.*
udp      0      0 *:dfspatch      *.*
udp      0      0 *:driver0       *.*
udp      0      0 *:driver3       *.*
udp      0      0 *:1036          *.*
udp      0      0 *:1035          *.*
udp      0      0 *:1034          *.*
udp      0      0 *:driver4       *.*
udp      0      0 *:1033          *.*
udp      0      0 *:driver2       *.*
udp      0      0 *:driver1       *.*
udp      0      0 *:1032          *.*
udp      0      0 *:1031          *.*
udp      0      0 *:1030          *.*
udp      0      0 *:1029          *.*
udp      0      0 *:1028          *.*
udp      0      0 *:1027          *.*
udp      0      0 *:1026          *.*
udp      0      0 *:dfsinfo       *.*
udp      0      0 *:1025          *.*
udp      0      0 *:1002          *.*
udp      0      0 *:1024          *.*
udp      0      0 *:sunrpc        *.*
```

Investigation of potential threats with Wireshark

The image shows the Wireshark network traffic analysis interface. The top menu bar includes File, Edit, View, Go, Capture, Analyze, Statistics, Telephony, Tools, and Help. Below the menu is a toolbar with various icons for file operations, capture settings, and analysis. The main window is divided into three panes. The top pane shows a list of captured packets with columns for No., Time, Source, Destination, Protocol, and Info. The middle pane displays the details of the selected packet (Frame 2114), including arrival time, time delta, frame number, length, and protocols. The bottom pane shows the raw packet data in hexadecimal and ASCII format.

Filter: Expression... Clear Apply

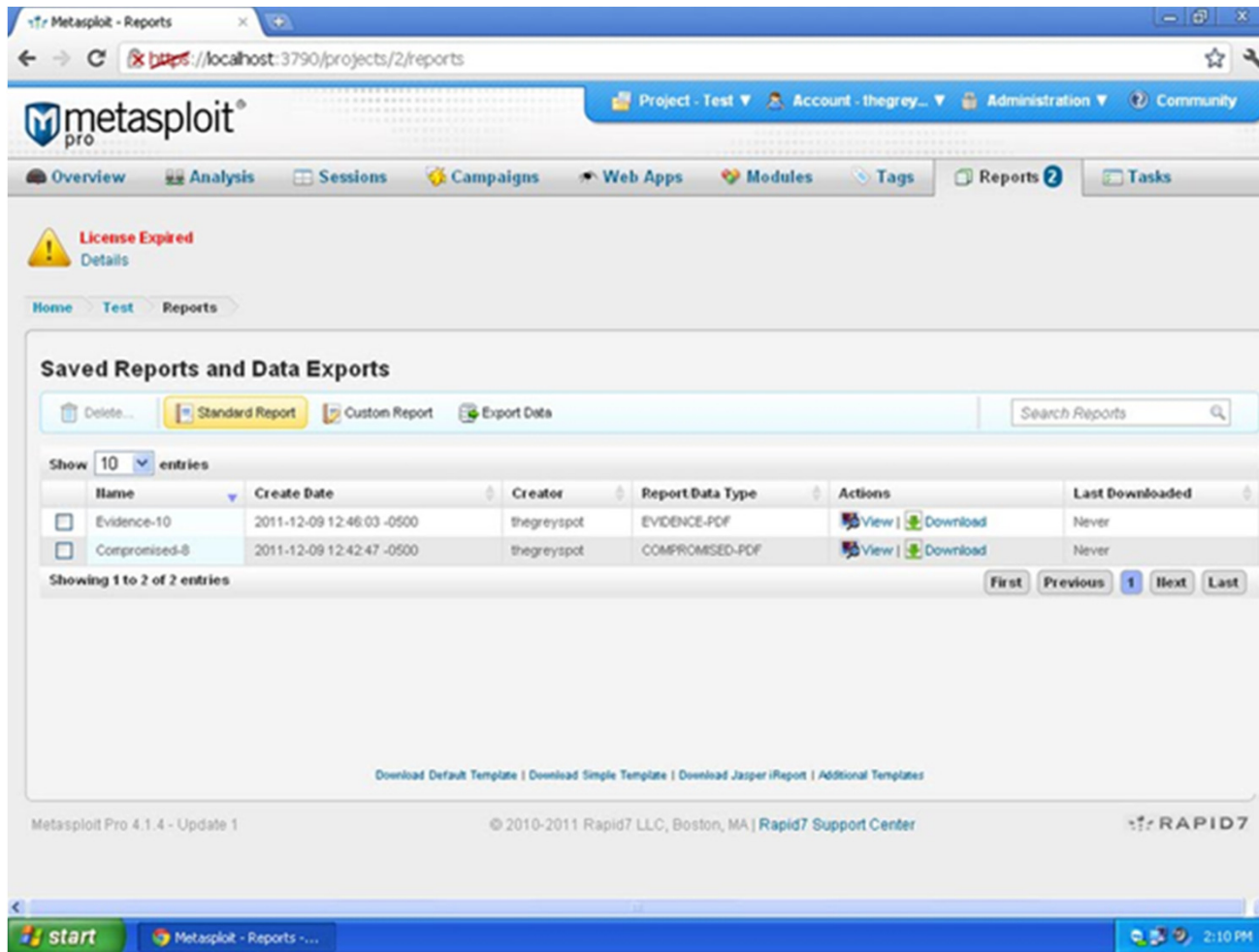
No.	Time	Source	Destination	Protocol	Info
2515	0.228332	69.88.163.28	69.88.163.30	TCP	[TCP keep-Alive ACK] rocketz > http [A
2519	0.393882	69.88.163.28	69.88.163.30	TCP	h323hostcall > http [ACK] Seq=3607 AC
2517	0.448178	69.88.163.28	69.88.163.30	TCP	[TCP keep-Alive ACK] h323gatedisc > h
2603	1.179155	69.88.163.28	69.88.163.30	TCP	msiccp > mctet-gateway [PSH, ACK] Seq
2605	1.189217	69.88.163.28	69.88.163.30	TCP	[TCP keep-Alive ACK] h323gatedisc > h
2618	1.501261	69.88.163.28	69.88.163.30	TCP	msiccp > mctet-gateway [ACK] Seq=43 A
2660	2.668288	69.88.163.28	69.88.163.30	TCP	[TCP keep-Alive ACK] h323gatedisc > h
2760	5.188412	69.88.163.28	69.88.163.30	TCP	[TCP keep-Alive ACK] rocketz > http [A
2774	5.400267	69.88.163.28	69.88.163.30	HTTP	GET /skins/basic_fw/hypertac2.screens
2782	5.550115	69.88.163.28	69.88.163.30	TCP	h323hostcall > http [ACK] Seq=6051 Ac
2790	5.628432	69.88.163.28	69.88.163.30	TCP	[TCP keep-Alive ACK] h323gatedisc > h
2841	6.746570	69.88.163.28	69.88.163.30	TCP	msiccp > mctet-gateway [PSH, ACK] Seq
2854	6.961199	69.88.163.28	69.88.163.30	TCP	msiccp > mctet-gateway [ACK] Seq=57 A
3141	11.548978	69.88.163.28	69.88.163.30	TCP	[TCP keep-Alive ACK] h323gatedisc > h
3198	12.269065	69.88.163.28	69.88.163.30	TCP	rocketz > http [ACK] Seq=2475 Ack=9493
3204	12.335893	69.88.163.28	69.88.163.30	TCP	msiccp > mctet-gateway [PSH, ACK] Seq
3232	12.632609	69.88.163.28	69.88.163.30	TCP	msiccp > mctet-gateway [ACK] Seq=71 A

Frame 2114 (54 bytes on wire, 54 bytes captured)
Arrival Time: Nov 21, 2011 02:26:45.950492000
[Time delta from previous captured frame: 0.000035000 seconds]
[Time delta from previous displayed frame: 0.000035000 seconds]
[Time since reference or first frame: 57.334088000 seconds]
Frame Number: 2114
Frame Length: 54 bytes
Capture Length: 54 bytes
[Frame is marked: False]
[Protocols in frame: eth:ip:tcp]
[Coloring Rule Name: Bad TCP]

```
0000 00 80 17 cc ae 40 00 0f 1f d6 a0 6e 08 00 45 00 .....@...n..E.
0010 00 28 24 81 40 00 80 06 05 64 45 58 a3 1c 45 58 .(.$@...dEX..EX
0020 a3 1e 06 c2 00 50 c6 53 fb b5 bc e3 d4 cd 50 10 .....P.S.....P.
0030 fa 7e d1 05 00 00 .....
```

Invalid filter | Packets: 5325 Displayed: 5325 Marked: 0 Dropped: 0 | Profile: Default

Investigation of potential threats with Metasploit



The screenshot displays the Metasploit Pro web interface for the 'Reports' section. The browser address bar shows `https://localhost:3790/projects/2/reports`. The interface includes a top navigation bar with links for Project, Account, Administration, and Community. Below this is a secondary navigation bar with tabs for Overview, Analysis, Sessions, Campaigns, Web Apps, Modules, Tags, Reports (active), and Tasks. A 'License Expired' warning is visible. The main content area is titled 'Saved Reports and Data Exports' and features a search bar and buttons for 'Delete...', 'Standard Report', 'Custom Report', and 'Export Data'. A table lists two reports: 'Evidence-10' and 'Compromised-8', both created on 2011-12-09. The table columns are Name, Create Date, Creator, Report Data Type, Actions, and Last Downloaded. The footer shows 'Metasploit Pro 4.1.4 - Update 1', copyright information for Rapid7 LLC, and the Rapid7 logo.

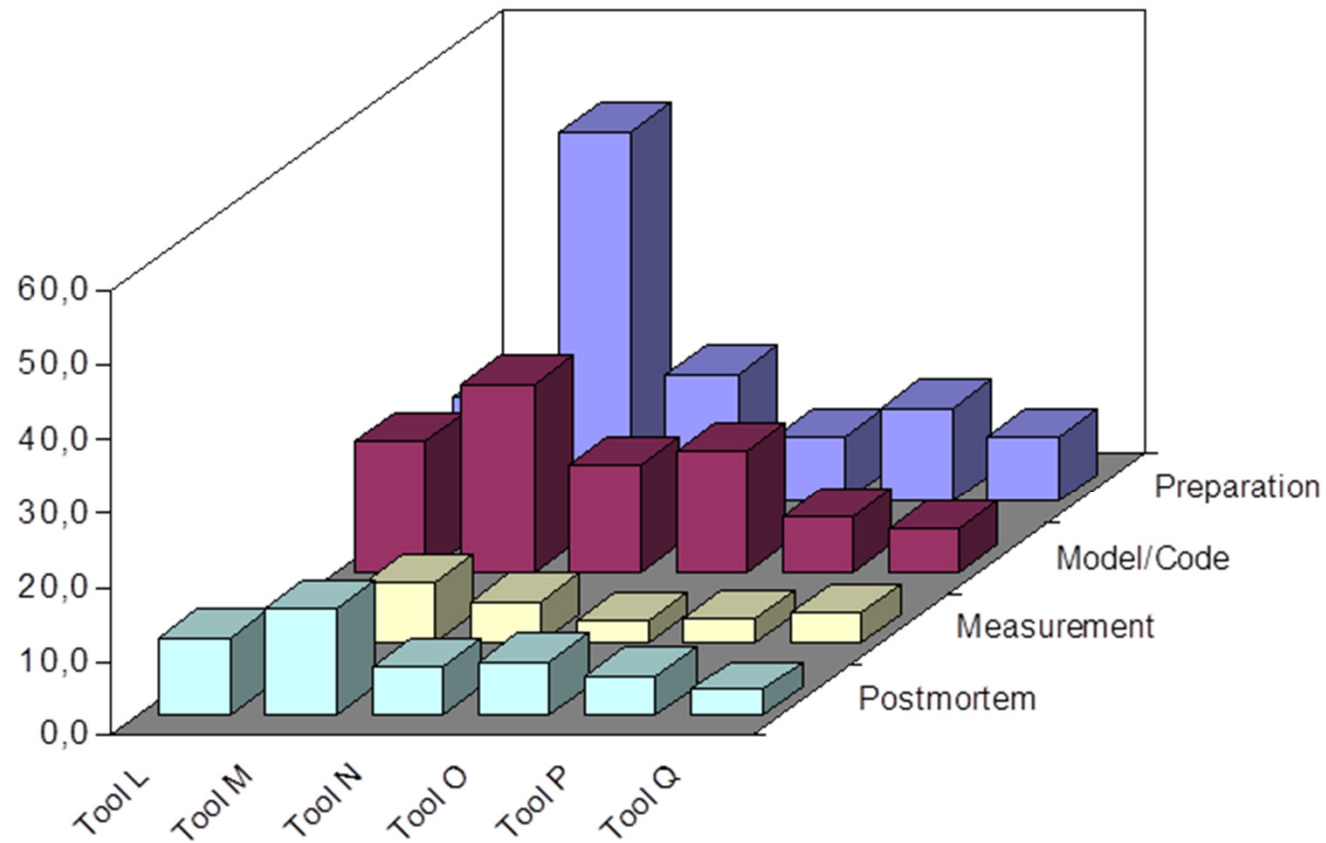
Metasploit Pro 4.1.4 - Update 1

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RAPID7

Name	Create Date	Creator	Report Data Type	Actions	Last Downloaded
Evidence-10	2011-12-09 12:46:03 -0500	thegreyspot	EVIDENCE-PDF	View Download	Never
Compromised-8	2011-12-09 12:42:47 -0500	thegreyspot	COMPROMISED-PDF	View Download	Never

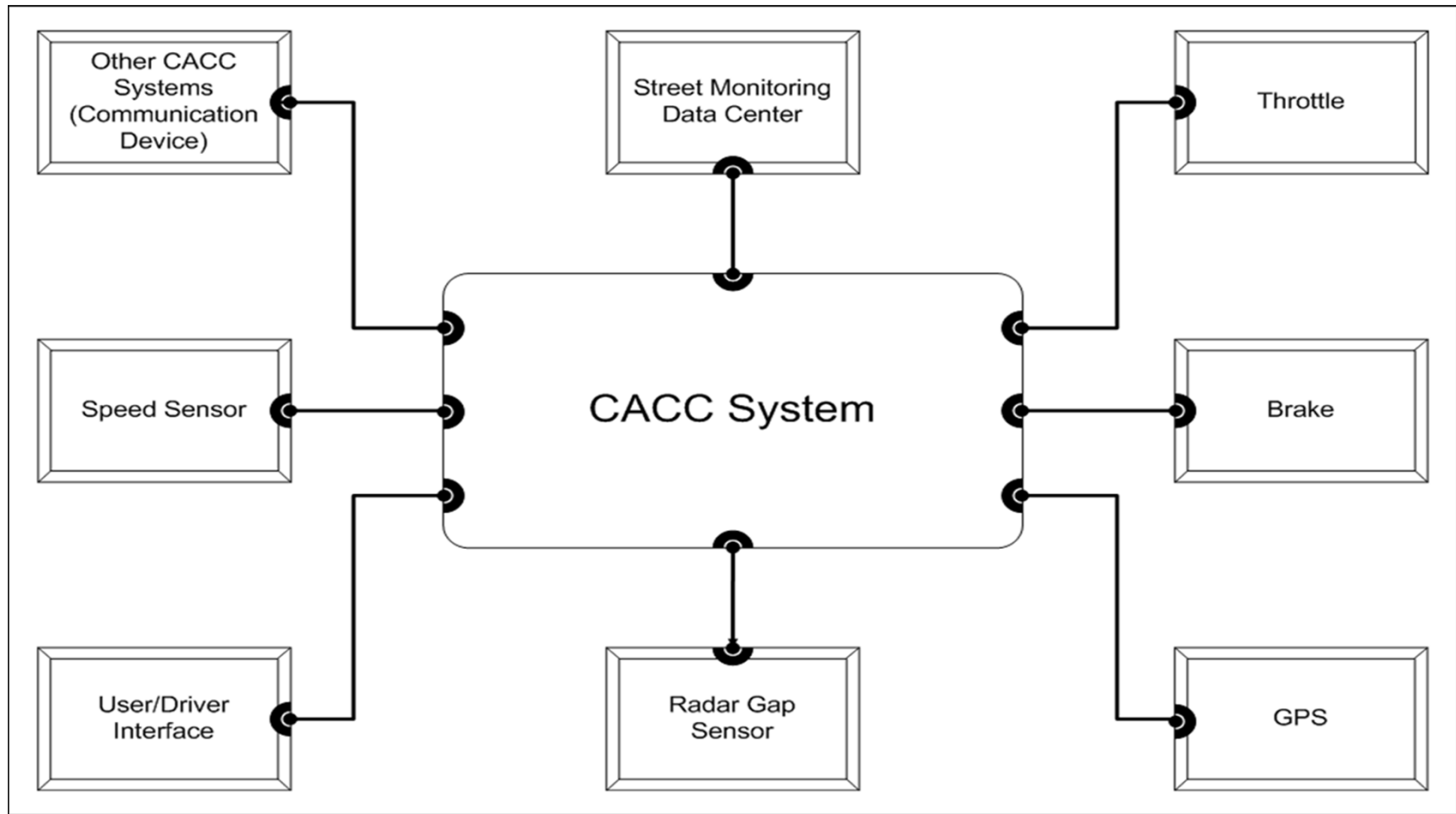
Analogy with safety assessment for using the collected data to assess security



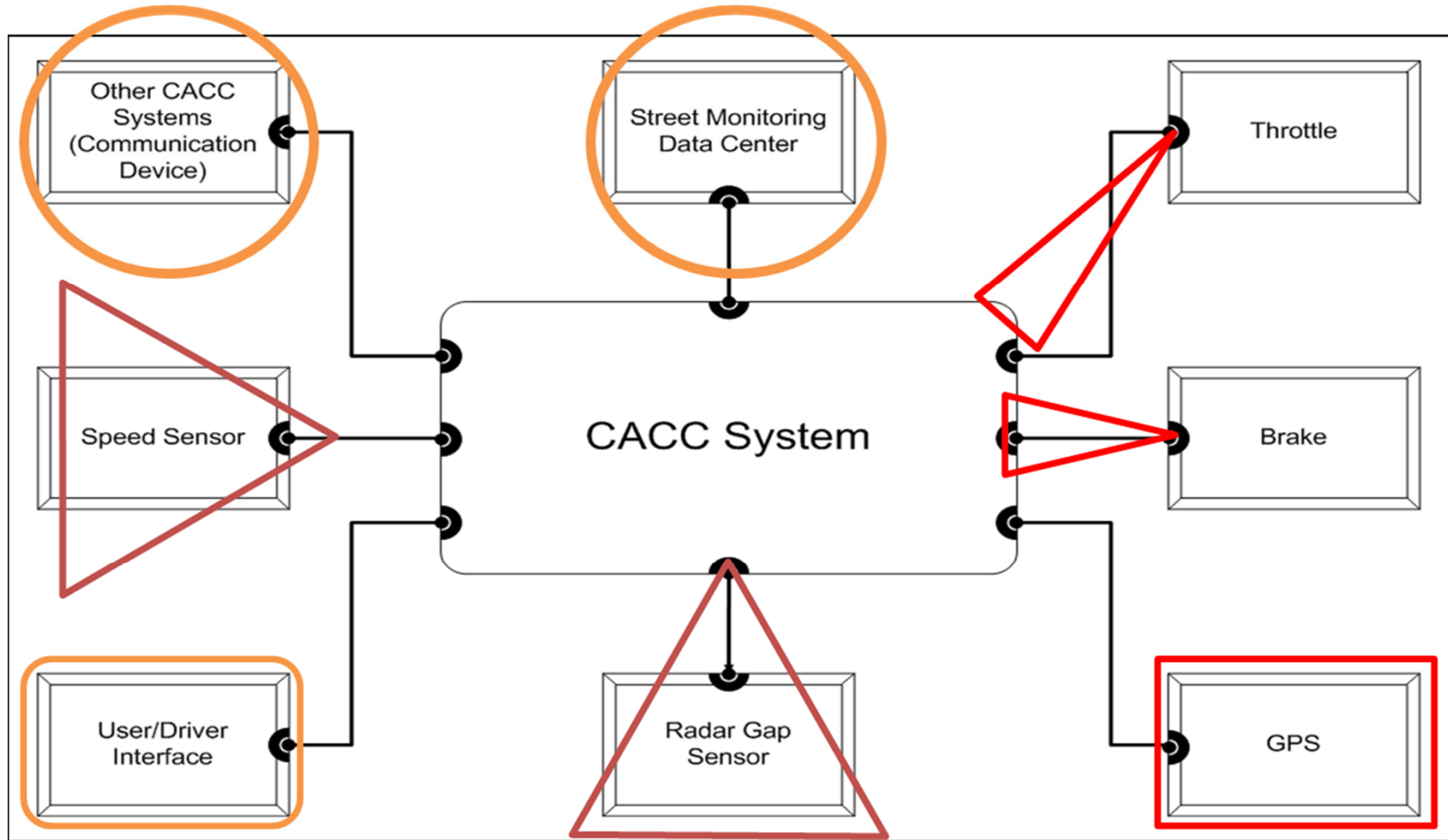
Our Approach to Simulation

- **Adopt acceptable system model**
- **Adopt data model**
- **Adopt failure model**
- **Use software tools**

Model of an Embedded System for Simulation Experiments

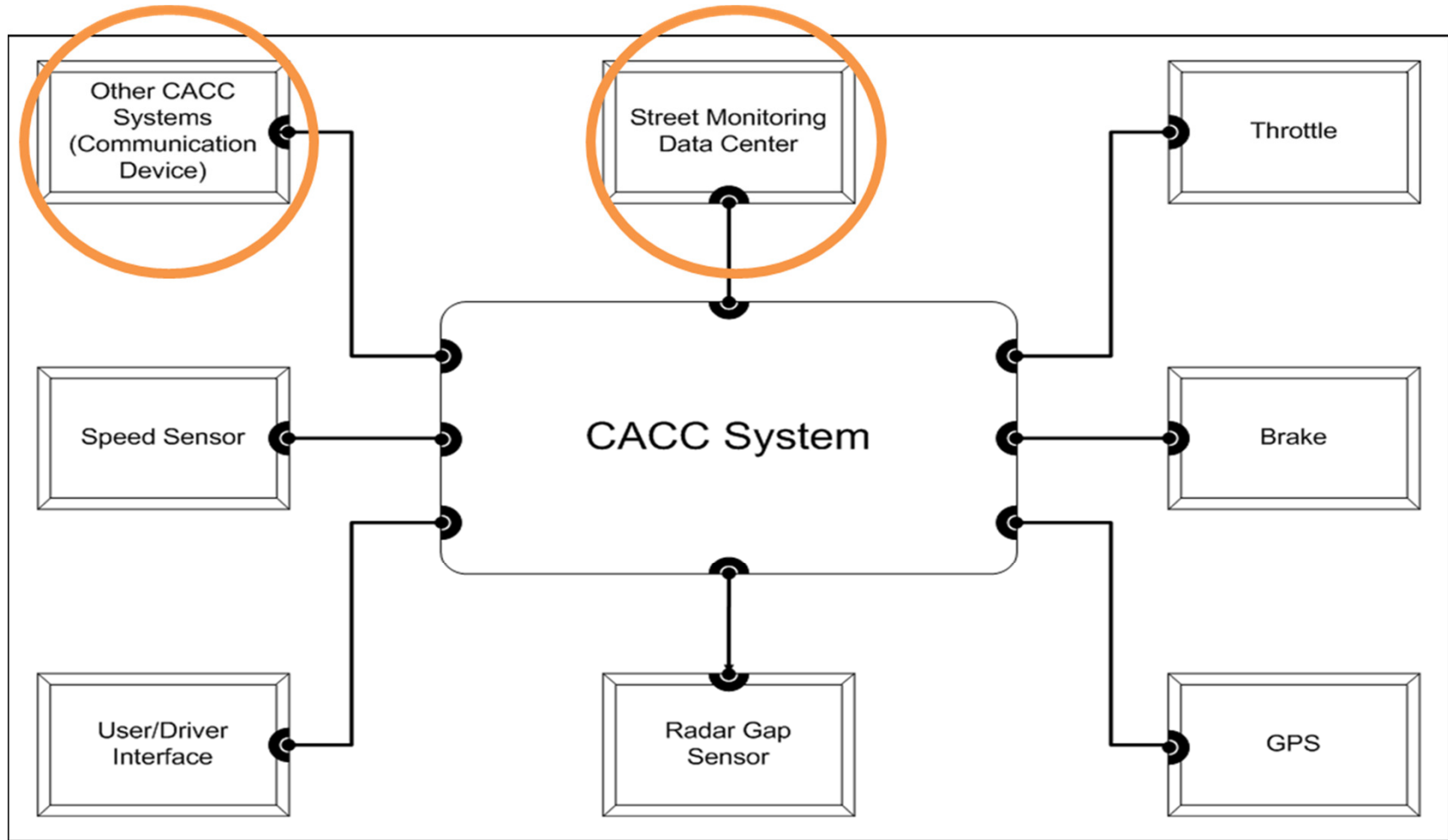


Model of an Embedded System for Simulation Experiments (outlining interfaces & full analogy with the Generic Model)



Model of an Embedded System for Simulation Experiments

- showing only the communication interfaces used



The Data Model: Specific Vulnerabilities

- Message Introduction: an untrue SMDC or Other CACC message is injected.
- Message Deletion: SMDC or Other CACC message is not received by the CACC system.
- Message Corruption: the contents of an SMDC or Other CACC message are altered before being received by the CACC system.
- Message Flooding: multiple frequent SMDC or Other CACC messages are received causing the CACC system to choke and not perform its required tasks within the deadlines.

The Failure Model

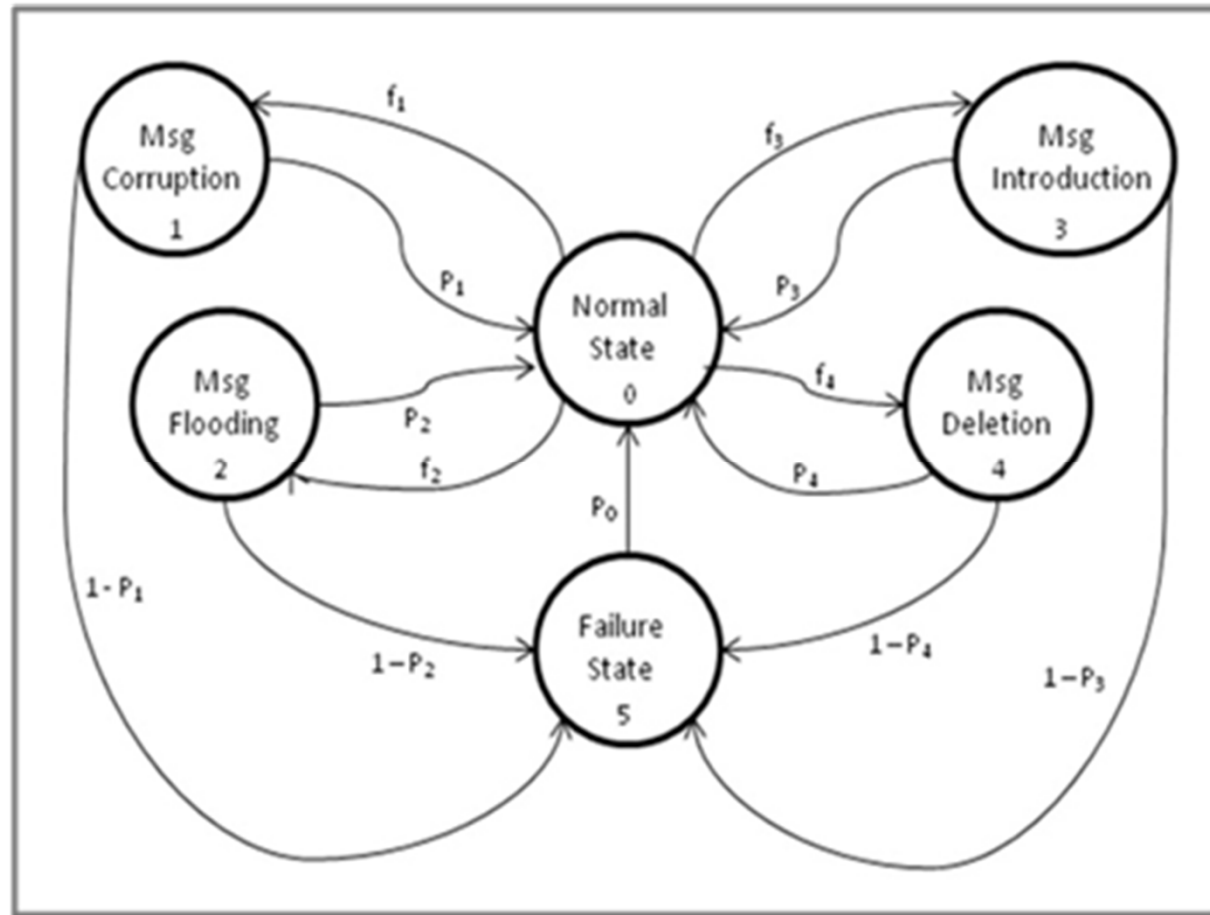
An essential assumption in this approach and the model we propose is that:

a security breach may cause degradation of system services and ultimately a failure.

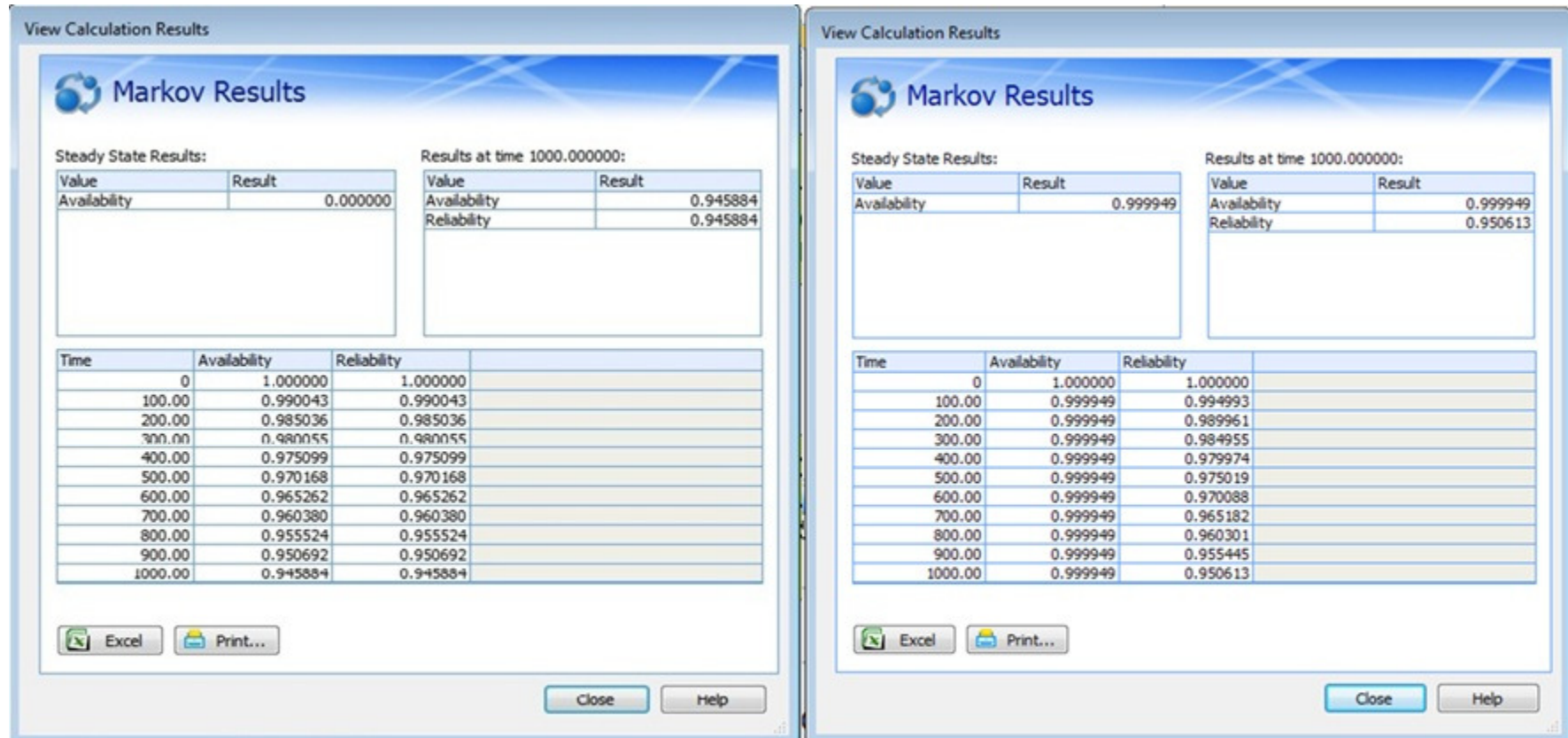
Thus, one can try and analyze the effects of a security breach by analyzing (simulating) the system behavior in the following states:

- **normal state**
- **failure state**
- **degraded states.**

Markov Model of a System with Repairs for Failure State



Results for No Repair and Repair Markov Model of a System



No repairs, availability 0.9459 Repair rate 0.9, availability 0.9999

Relx Markov modeling tool: <http://www.ptc.com/products/windchill/markov>

Conclusion

- **Assessment of operational security requires a multi-faceted approach**
- **Research on security assessment is pursued in three directions:**
 - **theory, experiment & simulation**
- **Analogies with physical sciences and other trustworthiness properties are essential**
- **Future work planned to be extended towards threat modeling**